Section 4: Physical Measures

Photos Courtesy of Katie Register and the Loudoun Wildlife Conservancy

Chapter 11

Temperature

Why Monitor Water Temperature?

The rates of biological and chemical processes depend on temperature. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Aquatic organisms are dependent on certain temperature ranges for optimal health. Optimal temperatures for fish depend on the species as some survive best in colder water. Benthic macroinvertebrates are also sensitive to temperature and will move in the stream to find their optimal temperature. For fish, there are two kinds of limiting temperatures: the maximum temperature for short exposures and a weekly average temperature that varies according to the time of year and the life cycle stage of the fish species. Reproductive stages (spawning and embryo development) are the most sensitive stages. If temperatures are outside this optimal range for a prolonged period of time, aquatic organisms are stressed and can die. Also, dramatic shifts in water temperature can cause stress to aquatic organisms.

What Do Your Water Temperature Measurements Mean?

Temperature changes can be caused by weather, removal of stream bank vegetation (which provides shade), impoundments (caused by barriers such as dams), cooling water discharge, urban storm water, and groundwater flowing into the stream. The water quality standards for water temperature in Virginia can be found in Table 11-1 below. Water temperature readings above these numbers indicate a violation of our state's water quality standards.

Table 11-1. Virginia Water Quality Standards for Temperature.

Estuarine Waters	Nontidal Waters – Coastal / Piedmont	Mountainous Zones	Stockable Trout Waters	Natural Trout Waters
Rise above natural temperature (arithmetic average over one hour)should not exceed 3°C.	32°C (maximum)	31°C (maximum)	21°C (maximum)	20°C (maximum)

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for temperature are discussed below.

Air Temperature

If air temperature is measured in addition to water temperature, then the air temperature reading should be measured prior to the water temperature. A wet thermometer can alter the air temperature reading. Air temperatures should be measured in the shade.

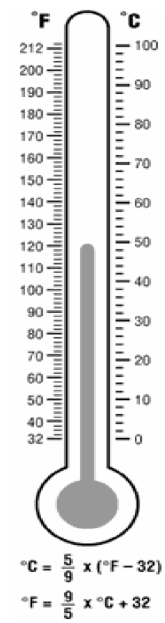


Figure 11-1. Scale for temperature conversion *(from Volunteer Estuary Monitoring: A Methods Manual, Second Edition).*

Choosing a Method

Temperature must be measured in the stream and may be measured with a thermometer or a meter. Temperature is measured in degrees Fahrenheit (F) or degrees Celsius (C). Temperature should be measured at the same place every time.

Thermometer

Alcohol-filled thermometers are preferred over mercury-filled because they are less hazardous if broken. Armored thermometers for field use can withstand more abuse than unprotected glass thermometers. Thermometer increments should be no more than 1°C.

Meters

Meters used for other measurements, such as pH or dissolved oxygen, may also be used to measure temperature.

Quality Assurance/Quality Control Issues

To assure accuracy, thermometers and meters should be compared with a National Institute of Standards and Technology (NIST) certified thermometer before use (just after purchase) and at least annually. You should compare these instruments at varying temperatures: an ice bath and room temperature. If the difference between your equipment and the

Where Can You Find a Certified Thermometer?

- DEQ Citizen Monitoring Coordinator
- Local college/university
- Local high school

certified thermometer is greater than 1º C during any of the comparisons, your equipment does not meet the Department of Environmental Quality's (DEQ) QA/QC requirements for data use in water quality assessments. A correction factor for thermometers that do meet this requirement can be developed if you have three comparison temperatures (ice bath, room temperature, and a warm water bath).

Summary of Water Temperature Monitoring Methods

Method	**Approximate Cost**	**Monitoring Level Depends Upon DEQ Approval of QAPP (see Appendix 9)**	**Organizations Using Method**
Field Thermometers (non-mercury)	$18.95	I, II, or III	- Alliance for the Chesapeake Bay and affiliate organizations - Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University) - Lake Anna Civic Association - Upper Rappahannock Watershed Stream Monitoring Program
Meters	$900-$5000 (multi-parameter meters)	I, II, or III	- Friends of the Shenandoah River and affiliate organizations - Loudoun Wildlife Conservancy

Chapter 12

Turbidity/Transparency and Total Solids

What Are Turbidity/Transparency and Total Solids?

Although the terms "turbidity" and "transparency" are often used interchangeably, they are different measurements. Turbidity is the cloudiness of water determined by measuring how the material suspended in water affects the water's clarity (how well light passes through the water column). Turbidity does not measure the amount of materials suspended in the water (such as soil, algae, and plankton); but it does measure the amount of light scattered by these particles. Turbid water appears murky or cloudy. Transparency, however, is the clarity (clearness) of the water determined by measuring how well light passes through the water. Both color and suspended materials can affect transparency.

Total solids are materials dissolved or suspended in water. Dissolved solids are less than 2 microns in size while suspended solids are larger than 2 microns. Total solids include soil particles, algae, plankton, dead organic matter, and dissolved inorganic solids such as chloride, nitrate, phosphate, iron, sulfate, magnesium, and calcium.

Why Monitor Turbidity/Transparency and/or Total Solids?

Turbidity/transparency and total solids can be useful indicators of discharges and runoff effects from construction, agricultural practices, logging activity, and waste discharges. Monitoring these parameters may help indicate whether erosion is increasing in a watershed. Turbidity can be caused by any activity that disturbs the stream banks, streambed, or surrounding land that causes sediment runoff into the stream. Turbidity often increases during and just after rainfall, especially in watersheds with a large number of impervious surfaces (rooftops, pavement, parking lots). Stormwater runoff from impervious surfaces rapidly increases the volume and velocity of stream flow, which erodes stream banks.

Sources of Turbidity

- Excessive algal growth due to nutrient enrichment
- Soil erosion from logging, agriculture, or construction
- Stormwater runoff
- Eroding stream banks
- Disturbance of bottom sediments
- Waste discharges

High turbidity levels affect SAV and dissolved oxygen levels. Turbidity reduces the amount of light penetrating the water, reducing photosynthesis and lowering the production of dissolved oxygen. Therefore, high turbidity can reduce SAV. Water temperature also increases with high turbidity levels because suspended particles absorb heat, which reduces dissolved oxygen levels (please refer to Chapter 4). Large amounts of suspended materials can clog fish gills, reduce disease resistance in fish, lower growth rates, and negatively affect egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, smothering fish eggs, benthic macroinvertebrates and the streambed habitat. Toxins also attach easily to suspended solids. The concentration of dissolved solids (such as chloride, nitrate, phosphate, iron, sulfate, magnesium, and calcium) may affect the water balance in the cells of aquatic organisms making it difficult for them to keep their position in the water column. This will in turn affect the organism's ability to maintain the proper cell density.

What Do Your Turbidity/Transparency and Total Solids Results Mean?

Although there are no water quality standards in Virginia for total solids or turbidity, this information can be useful when looking at trends and can provide information about local land use and sediment control programs. It is important to remember that turbidity/transparency does not measure the amount of suspended solids or the rate of sedimentation. Measurement of total solids is a more direct measure of the amount of material suspended and dissolved in water. Total solids are related closely to stream flow and velocity. Any change in total solids over time should be measured at the same site at the same flow (refer to Chapter 15 for more information on stream flow). Since algae can be the major source of suspended solids in estuarine waters, seasonal variations must also be taken into consideration when monitoring turbidity and total solids.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Chapter 1 outlined a number of factors that every volunteer water quality monitoring program should consider. In addition to those summarized in Chapter 1, several considerations specific to monitoring for turbidity/transparency and total solids are discussed below.

When to Sample

To gain information that would be useful for looking at trends, turbidity or total solids should be monitored relatively frequently year-round for several years. Since turbidity often increases during and immediately after a rainfall, you may consider collecting additional turbidity data to capture the effects of runoff.

Choosing a Method

Secchi Disk

Secchi disk *(photo courtesy of Alliance for the Chesapeake Bay)*.

This weighted disk is used to measure transparency (an integrated measure of light scattering and absorption) by lowering the disk into the water and measuring the depth where the disk disappears (Secchi depth). The clearer the water the greater the Secchi depth. Many volunteer programs in lakes or tidal, estuarine waters use the Secchi disk because it is inexpensive and easy to use.

Secchi disk lines may shrink over time and lines that are marked for measurements should be calibrated regularly. Using a rope that has minimal shrinkage is also recommended. The Secchi disk is not appropriate for use in shallow, fast moving waters.

Transparency Tube

This is a clear, plastic tube with a pattern on the bottom (sometimes a miniature Secchi disk). Water is poured into the tube and the measurement (usually in centimeters) where the pattern disappears is recorded. Waters with extreme colors can interfere with this measurement. The readings from transparency tubes from different manufacturers cannot be compared. This instrument was developed to measure transparency in waters where the Secchi disk is not appropriate (site is too shallow, the flow is too rapid, or there is no dock or pier).

Turbidity Test Kits

Field test kits can be used to measure turbidty. A standardized turbidity reagent is added to a tube of clear water until its cloudiness matches your water sample.

Turbidity Meter (Nepholometer)

A turbidity meter measures turbidity in Nephelometric Turbidity Units (or NTUs). This instrument is not currently used by any citizen monitoring programs in Virginia. A turbidity meter may be used in a laboratory or in the field to measure the turbidity of water samples.

Laboratory Analysis

Lab analysis can be used to determine turbidity and total solids (total dissolved solids or total suspended solids). Total solids must be analyzed in a laboratory by weighing a known volume of sample water and filtering the water sample.

Even laboratory analysis requires strict quality assurance and quality control methods. Recommended QA/QC measures include:

- Proper Preservation: Cool sample to less than 4ºC with a holding time of up to seven days.
- Field duplicates: A field duplicate is simply a second water sample taken at the same time as another sample to measure the reproducibility of the monitor, method and/or analyst. It is recommended that field duplicates are collected randomly for 10% of your samples (for a large sample size, 5% is acceptable). For example, if you collect 50 samples, you should collect field duplicates at 5 of those sites and label the duplicate samples.
- Field equipment blanks are only necessary if water samples are collected in a bucket or other sampling device and transferred into the

sample container. A field equipment blank is simply a contaminant-free sample (distilled or deionized water) used to detect contamination of the collection device or cross-contamination between sites. A field equipment blank is collected and transferred in the same manner as the stream water sample. It is recommended that you collect field equipment blanks randomly for 10% of your samples (for a large sample size, 5% is acceptable).

Summary of Turbidity/Transparency and Total Solids Monitoring Methods

Method (Vendor and Model #)	**Approximate Cost**	**Monitoring Level (see Appendix 9)**	**Organizations Using Method**
Secchi Disk	$30-$35	I	- Alliance for the Chesapeake Bay and affiliate organizations - Ferrum College (Smith Mountain Lake & Claytor Lake Programs) - Lake Anna Civic Association
Transparency Tube (Lawrence Enterprises # TT or TTG)	$34-$49	I	- Alliance for the Chesapeake Bay and affiliate organizations - Appomattox River Water Quality Monitoring Program (Clean Virginia Waterways / Longwood University)
Turbidity Test Kit (LaMotte #7519)	$46	I	- Northern VA Soil and Water Conservation District
Turbidity Meter (field or lab)	$800	I	- Friends of the Shenandoah River and affiliate organizations
Lab analysis of total suspended solids	$5.00*	I	- Alliance for the Chesapeake Bay and affiliate organizations - Historic Green Springs

*This cost is based upon submitting samples to the state laboratory, the Division of Consolidated Laboratory Services. This lab is only available to government organizations and nongovernmental organizations that receive state funding.

Chapter 13

Salinity

What is Salinity?

Salinity is the amount of dissolved salts in water. Salinity of tidal rivers and estuaries gradually increases as you move from freshwater tributaries toward the ocean. The freshwater streams and rivers have salinity levels of 0.5 ppt (parts per thousand) or less. Salinity of seawater is relatively constant at more than 30 ppt.

Why Monitor Salinity?

Salinity levels affect the distribution of plants and animals in estuarine environments. Some species can only tolerate certain levels of salinity while others may be able to adjust to any salinity ranging from freshwater to saltwater.

Salinity influences the saturation levels of dissolved oxygen. The amount of dissolved oxygen (DO) the water can hold decreases as the salinity increases. If you are using a meter to measure DO in estuarine waters, you may need to know the salinity level in order to properly calibrate the meter. Salinity can have a role in increasing turbidity by causing dissolved particles in fresh water to clump together upon entering the saltwater. Salinity and water temperature determine the stratification of estuarine waters. Cold, saltwater is denser than warm, freshwater and will sink below the freshwater. Tides and the wind can mix these waters and eliminate the stratification.

What Do Your Salinity Results Mean?

Although there is not a water quality standard in Virginia for salinity, this information can be useful when you are looking at trends, distribution of plant and animals, and other water quality parameters. Salinity is measured in parts per thousand (ppt).

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Weather and Season

During wet weather periods, freshwater enters the estuarine waters lowering salinity levels. Higher salinity levels are found during dry weather periods since less freshwater dilutes the estuarine waters allowing saltwater to intrude into tidal rivers and streams. Seasonal variations and storms also help mix these waters.

Choosing a Method

Density Using a Hydrometer

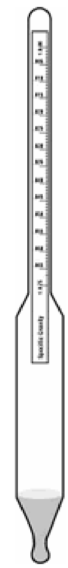


Figure 13-1. A hydrometer can be used to calculate salinity based upon the density of the water *(from Volunteer Estuary Monitoring: A Methods Manual, Second Edition).*

Hydrometers are inexpensive, fragile and very consistent over time. The hydrometer measures the specific gravity of the water sample, which is the sample's density compared to the density of freshwater. As the salinity of water increases so does its density. Specific gravity is affected by both dissolved and suspended solids; whereas, salinity is based upon dissolved solids only. Therefore, salinity readings measured with a hydrometer are higher when suspended solids are present, especially in low salinity waters.

Refractivity Using a Refractometer

A refractometer is not influenced by suspended solids like the hydrometer. As light travels from air into water, the refractometer measures the change in the light's direction. The extent of this change in direction is influenced in a predictable manner by the salinity of the water. To yield accurate results, the refractometer must be close to the temperature of the sample water.

Meter

Some conductivity meters can calculate salinity from the conductivity reading (conductivity is discussed in Chapter 14). This instrument is not currently used by any citizen monitoring organizations in Virginia. Samples may be transported to a central location for measurements with the meter. See chapter 14 for more information on using a conductivity meter.

Summary of Salinity Monitoring Methods

Method)	**Approximate Cost**	**Monitoring Level (see Appendix 9)**	**Organizations Using Method**
Hydrometer (Greers Ferry 1.000 X 1.070) *Need jar (LaMotte #2-2149)	$50 for hydrometer and jar	I	- Alliance for the Chesapeake Bay and affiliate organizations - Assateague Coastal Trust
Refractometer	$90-$350	I	- Alliance for the Chesapeake Bay and affiliate organizations
Conductivity Meter	Chapter 14	I	None known

Chapter 14

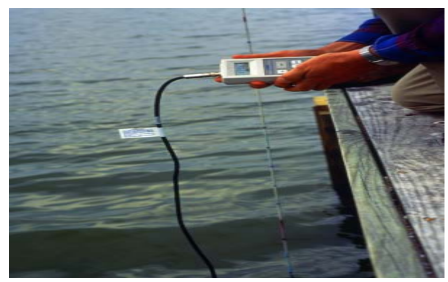
Conductivity

What is Conductivity?

Conductivity (known as specific conductance) is the ability of water to pass an electrical current. Conductivity is affected (raised) by inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge); and sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Oils and many organic compounds do not conduct an electrical current very well and therefore, do not affect conductivity.

The geology of the area through which a stream flows is one of the most important factors affecting conductivity. Streams in areas with granite bedrock usually have lower conductivity levels because granite is composed of relatively inert material that does not conduct an electrical current very well. Alternatively, streams in areas with clay soils usually have a higher conductivity because of the presence of materials that conduct electrical currents. Ground water inflows can have the same effects depending on the bedrock they flow through. Warmer water has a higher conductivity than colder water.

Why Monitor Conductivity?



Volunteer measuring conductivity with a meter *(photo courtesy of Alliance for the Chesapeake Bay)*.

Conductivity is a useful measure of general water quality. Each stream generally has a relatively constant range of conductivity. Once you establish the baseline conductivity range for a stream, you can compare regular conductivity measurements. Significant changes in conductivity may indicate a discharge or another source of pollution is affecting the stream.

Discharges to streams can affect the conductivity depending on the type of discharge. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate (which would conduct an electrical current well). An oil spill, however, would lower the conductivity. Heavy rains also lower the conductivity since rainwater has a very low conductivity.

What Do Your Conductivity Results Mean?

Although there are no water quality standards in Virginia for conductivity, this information can be useful when you are looking at trends and general water quality. As discussed in the section above, significant changes in conductivity measurements can indicate potential problems that may need further investigation.

Sampling and Quality Assurance/Quality Control (QA/QC) Considerations

Conductivity is reported at 25°C and is measured in micromhos per centimeter or microsiemens per second. Samples may be transported to a laboratory for the conductivity measurements.

Conductivity meters should be calibrated with standard conductivity buffers (solutions of known specific conductance values) for the range where specific conductance values usually occur. Additionally, the calibration should be confirmed at the end of the sampling day (this is referred to as a "post check") to determine if the meter has drifted throughout the sampling day. The post check should be conducted similar to the calibration without pressing the calibration button.

Summary of Conductivity Monitoring Methods

Method	**Approximate Cost**	**Monitoring Level (see Appendix 9)**	**Organizations Using Method**
Meter (a multi-parameter meter is more cost-effective than a single parameter meter)	$60-$1000 (conductivity only) $900-$5,000 (multi-parameter)	I	Ferrum College (Smith Mountain Lake & Claytor Lake Programs)

Chapter 15

Stream Flow

What is Stream Flow?

Stream flow (discharge) is the volume of water that passes a given stream cross section (total width of stream) within a given period of time. Flow is measured by determining the depth and width of a stream and the velocity (speed at which water travels). The area (width multiplied by depth of a stream) multiplied by the velocity gives the discharge. Flow is affected by weather (increases during rain events), seasons (decreases during summer due to evaporation and uptake by vegetation), water withdrawals, water discharges, and the groundwater table level.

Why is Stream Flow Important?

Stream flow impacts water quality and the living organisms and habitats in the stream. The amount of pollution a stream can receive without significantly affecting the water quality partially depends upon the stream flow. Swiftly flowing, large rivers have a greater capacity to dilute pollution than small streams. Stream velocity, which is partly determined by the volume of water in the stream, affects the kinds of organisms that live in the stream (some organisms prefer faster flowing streams while others prefer slower flowing streams). Sediment entering slow flowing streams will settle quickly, while sediment in fast flowing streams will remain suspended longer. Dissolved oxygen is also affected by stream flow since fast moving streams are better aerated, which results in higher dissolved oxygen levels.

What Do Flow Measurements Mean?

Since flow is a function of water volume and velocity, it is usually expressed as cubic feet per second (ft^3/sec). Stream flow is needed to calculate how much of a pollutant the stream can receive without violating a water quality standard.

Flow data collected by volunteer monitoring programs is not typically used for TMDLs and permit applications. Data users that generally use flow data for scientific analysis (rather than permitting or other legal matters) have demonstrated an interest in any flow data. Potential uses include: conducting minimum in-stream flow analysis; relating flow measures to Wolman Pebble Counts (and Riffle Stability Index develop by the United States Forest Service); and relating flow measures to benthic macroinvertebrate populations.

Measurement Considerations

When considering measuring flow in your watershed, it is recommended that you first determine if your watershed has a stream gauge collecting flow data operated by the Department of Environmental Quality (DEQ) or the U. S. Geological Survey (USGS). USGS and DEQ work cooperatively to maintain a network of approximately 161 continuous stream flow gauging stations across Virginia. The flow data for most of these stations can be found in real-time (updated every 1-4 hours) online at http://www-va.usgs.gov. The flow of most streams in Virginia is not determined on a consistent basis. In most cases where real flow data does not exist, flow is estimated by interpolating flow data from an existing gauge to the stream in question. DEQ and USGS measure flow using methods derived from USGS (as outlined in Rantz, S.E., and others, 1982, *Measurement and Computation of Streamflow: Volume 2. Computation of Discharge.* U. S. Geological Survey Water-Supply Paper. 2175).

One method for measuring discharge (the method most commonly used by DEQ and USGS staff) is conducted by wading into the stream. The width of the stream is divided into small units (stations) and several measurements are taken at each station: depth, width, and velocity. There are several different ways to measure velocity. One way involves floating an object downstream and measuring the distance it travels in a particular amount of time. Another method for measuring a stream's velocity uses a current meter. At each station, the depth (in feet) is multiplied by width (in feet) by the velocity (in feet per second). The product of these three numbers gives the discharge for that station in cubic feet per second. The discharges for each station are added to obtain the total discharge for the stream at that cross section.

The Virginia Save Our Streams Program (VA SOS) evaluated how flow measures are collected across the country and how flow measures collected by volunteers can be used. From this research, VA SOS found that flow is not commonly measured by citizen monitoring programs due to the difficulty in obtaining data that is useful to water quality professionals. It is important for volunteer monitoring programs to obtain the most accurate estimate of stream flow possible with the equipment and expertise of the organization.

Summary of Stream Flow Monitoring Methods

Method	**Approximate Cost**	**Monitoring Level (see Appendix 9)**	**Organizations Using Method**
Estimate using float and cross sectional area, length, and velocity	Negligible (most items needed for this method can be found at home)	I	None known
Flow Meters	\$300-\$1500	I	- Loudoun Soil and Water Conservation District

Chapter 16

Visual Stream Assessments (Stream Walks)

What is a Visual Stream Assessment?

A visual stream assessment is basically a "stream walk" to evaluate stream health by assessing the physical habitat and potential impacts along a stream channel. A stream walk may be done on foot or by using a boat or canoe depending on the stream.

Why Conduct a Stream Walk?

Conducting a stream walk can produce valuable information about your stream. You may wish to conduct a stream walk prior to water quality monitoring to determine where to focus monitoring efforts. A stream walk may be performed in conjunction with water quality monitoring to help you formulate some theories about what may be impacting the monitoring data. Some stream walks may be conducted to determine potential impacts on stream health with no plans of monitoring.

How Can You Use the Information from a Stream Walk?

Stream walks may collect qualitative (such as rating erosion) or quantitative (such as mapping pipe outfalls) information which will ultimately determine the use of the information gathered. This information can be used to establish baseline conditions and then later stream walks can document changes over time. Some organizations may use the information to determine areas where best management practices (BMPs) are needed. BMPs are pollution control techniques used to reduce pollution from agriculture, timbering practices, construction, marinas, and stormwater. For impaired streams, the stream walk information may be useful background information for developing Total Maximum Daily Load (TMDL) Plans and TMDL Implementation Plans.

How Do You Conduct a Stream Walk?

There are several methods utilized for conducting stream walks, which are based upon similar elements. These methods often are adapted specifically to the stream and the goals of the organization conducting the stream walk.

The James River Association (JRA) developed a draft *Physical Assessment Guide* based upon a number of methods, including *Streamwalk* (developed by the U. S. Environmental Protection Agency's (EPA) Regional Office in Seattle, Washington.

> For more information on the draft Physical Assessment Guide, please contact the James River Association at 804-730-2898 or http://www.jamesriverassociation .org.

In association with the Virginia Save Our Streams Program, JRA is field-testing and revising the guide. The goal of this guide is to develop a method specific for Virginia that can be adapted as needed by anyone interested in conducting a stream walk. This method is primarily a visual observation of stream habitat and physical attributes.

Other methods used in Virginia include: a protocol used by the Mattaponi and Pamunkey Rivers Association (contact information is in Appendix 1) based on a Maryland Department of Natural Resources protocol and a U. S. Department of Agriculture (USDA) protocol[1]. In general, stream walk protocols require that you walk, canoe, or boat along a defined stretch of stream while observing water and land conditions, land and water uses, potential pollution problems and changes over time. These observations typically are photographed and recorded on maps and data sheets.

[1] U. S. Department of Agriculture. 1998. *National Water and Climate Center Technical Note 99-1:* S*tream Visual Assessment Protocol.* December.

Chapter 17

Riparian Forests and Stream Health

This chapter has been excerpted and adapted, with permission, from Austin, Samuel H. 1999. *Riparian Forest Handbook 1*, Virginia Department of Forestry, December.

What is a Riparian Forest and Why is it Important?

A riparian forest is simply a streamside forest. The benefits of riparian forests are numerous, from protecting the physical stream environment to removing or transforming nutrients, sediments and pollutants. Overall, riparian forests lead to improved water quality.

Riparian forests protect the physical stream environment in a number of ways:

- Riparian forests help reduce fluctuations in water temperature and regulate light levels reaching a stream resulting in a more stable habitat for plant and animal life.
- Riparian forests provide woody debris for increased habitat diversity for benthic macroinvertebrates and fish.
- Leaf litter and algal (microscopic plant) production, the two primary sources of food energy inputs to streams, are intimately tied to the presence of riparian forests. Studies show that the algal community of a stream well-shaded by older trees is dominated by single-celled algae (diatoms) throughout the year. Streams in deforested areas often contain many thread-like (filamentous) green algae, and few diatoms. While some macroinvertebrates such as crayfish readily consume filamentous green algae, most herbivorous species of stream macroinvertebrates have evolved mouth parts specialized for scraping diatoms from the hard surfaces and cannot eat filamentous algae. Streamside deforestation is one factor that can cause macroinvertebrate diversity to decline.
- Absence of a streamside forest can change channel morphology (the dimension, pattern, and profile of a channel) resulting in habitat loss.

Healthy forest streams have a stable dimension, pattern, and profile that fit the natural landform of the surrounding landscape. Stable natural channels tend to be sinuous and relatively narrow with little exposed or eroding stream bank. They also have access to an active flood plain. Without trees, stream banks may erode creating an unnaturally wide channel. Water velocities may increase as water moves without woody debris to absorb the energy. Faster water combined with altered channel shape can cause bank scour, stream straightening, and excess sediment deposition in the streambed. Each of these can create a degraded environment that supports fewer aquatic plant and animal species.

Eroded stream bank *(photo courtesy of Alliance for the Chesapeake Bay)*.

Stream systems are dynamic, but the change in stable stream systems occurs very slowly within the context of the landscape. Throughout history, humans altered the landscape causing profound effects on the landscape, streams, and rivers. Sections of streams and rivers within many watersheds shifted from a stable geometry to an unstable geometry. These adjustments continue today. The effects of human activity within the watershed are pronounced and visible on the landscape. As land is cleared, a cycle of events evolves that continues to degrade the stream system.

Why Evaluate Riparian Forests?

Evaluation of your stream's riparian forest may require additional training and technical expertise. However, this activity may be particularly rewarding for volunteer organizations interested in taking water quality monitoring to another level - restoration.

How Can You Use the Information from Your Evaluation?

The Virginia Department of Forestry (DOF) developed *Riparian Forest Handbook 1* along with a companion computer disk to guide you in evaluating a portion of a stream that you may wish to restore. There are regulations and permits required in most localities that pertain to stream restoration. It is strongly recommended that volunteer organizations conduct these evaluations and any restoration work with the assistance of a professional organization, such as a local government or local soil and water conservation district. The computer disk contains programs to assist you in characterizing your stream. Information from your measurements can help you select appropriate restoration activities. Restoration activities include:

> The *Riparian Forest Handbook 1* and companion programs may be obtained by contacting the Virginia Department of Forestry at (434) 977-6555.

- Exclusion: Limiting activity near the stream, such as fencing out livestock.
- Planting: Establishing trees along the bank of a stream.
- Channel Modification: Changing the shape of the channel to restore its natural meander, width and depth.

How Do You Evaluate Riparian Forests?

The aforementioned handbook and companion computer disk provide a detailed methodology to evaluate a riparian forest. For evaluating riparian forests, the handbook describes how to measure the departure from desired conditions using three benchmarks (discussed in detail below): the three zone riparian buffer; normal values of stream dimension, pattern, and profile; and normal values of stream particle size and distribution. In any investigation of the departure from desired conditions, it is important that measurements are made and compared for all three benchmarks.

First, select a stream area to evaluate while considering the questions in Chapter 1. As with conducting water quality monitoring, you should research existing information about your stream before collecting your measurements. Take time to review regional climate data, geology, land types, vegetation, historic land use and any forest plan guidance.

Benchmark 1: Streamside Vegetation in the 3 Zone Riparian Buffer

The 3 zone riparian buffer is an accepted minimum standard for vegetation adjacent to streams and rivers. The area immediately adjacent to the stream (Zone 1) should be comprised of larger woody plants and tress. The roots of this vegetation provide structural support for the stream bank. Zone 2 (the next 60 feet beyond Zone 1) should be a contiguous forest to filter sediments and nutrients from runoff. Beyond Zone 2 should be an area of contiguous forest, perennial grasses, or non-woody plants. To evaluate this benchmark, you will determine the dominant type of plant cover and the density of that cover.

Benchmark 2: Stream Channel Dimension, Pattern, and Profile

Measurements of stream dimension (shape of stream when viewed in cross-section), pattern (shape of stream when viewed from above), and profile (shape of stream when viewed from the "side" along its gradient, i.e. pools and riffles) are used to determine if a stream has a stable "hydrology" and "geology." A stable stream migrates slowly across its valley over thousands of years. Having evolved slowly in an undisturbed landscape, the dimension, pattern, profile, and water regime of a stream achieve a dynamic equilibrium within the surrounding environment. This equilibrium is an integration of the landscape and historic rainfall patterns upstream.

The first step is to determine hydraulic geometry by measuring a cross-section and a longitudinal profile of the stream channel, using surveying equipment. Calculations based upon these measurements (the software for the *Riparian Forest Handbook 1* includes a program that makes the calculations) are used to categorize the stream according to the Rosgen stream classification system. This classification system is commonly used to group streams with similar configurations.

Benchmark 3: Stream Channel Particle Size Distribution

In addition to streamside vegetation and hydraulic geometry, the sediment load of a stream is a useful benchmark of stability. As a stream system evolves over time, it develops a characteristic set of sediment particle sizes in the streambed. These particles move through the channel over time. The quantities of each size of material depend on the geology of the watershed and the energy of water flow in the system. In an undisturbed stream system, the distribution of particle sizes indicates the natural sediment load of the streambed (known as "bed load"). Any abrupt change in vegetation, land surface features, or length, width, depth and shape of portions of the stream channel can cause streams to adjust to recapture a stable shape. A frequent consequence of these adjustments is a shift away from the normal sediment particle size distribution. A pebble count (where particles are selected and measured) is typically used to determine particle size distribution.